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This report summarizes earlier work on the effects of the repetition of sleep deprivation periods and the interaction of age and sleep deprivation. Preliminary results are presented of the effects of placement of four hours of sleep time during 72 hours of performance without sleep. Three nap schedules were used: two two-hour periods prior to the 2nd and 3rd night time period ("preparatory" naps), two two-hour periods after the 1st and 2nd night ("recovery" naps) and a four hour nap period prior to the

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second night. A computer programmed battery of tests was used which included tests established as sensitive to sleep loss (auditory vigilance, addition and subjective scales), and a cognitive battery (memory tasks, anagrams, word detection, visual search, line judgements with various feedbacks, object usage, reasoning, and digit symbols). Using the performance during the third night, there was a limited but non differential effect of these schedules compared to a no nap control group.

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SLEEP DEPRIVATION AND PERFORMANCE:
OLDER AGE PERFORMANCE AND LIMITED SLEEP PERIOD USE

Final Report

Wilse B. Webb, PH. D.

May, 1984

Supported by

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
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Summary

The purposes of these experiments were to assess the effects of three variables on performance in extended periods of time without sleep: the effects of prior repetition of performance in such conditions, the effects of age and the effects of limited interjected sleep periods.

A computer-based battery of performance tasks was used which included subjective measures, short and long term monitoring tasks, continuous production tasks, precision measures, and an extensive battery of cognitive tests.

Repetition of extended performance across 48 hours without sleep at four monthly intervals did not offset performance decrements. Where effects were obtained, performance decrements were enhanced.

In two experiments with 40-50 year old subjects and 50-60 year old subjects in extended performance of forty-eight hours without sleep, where differences were obtained, older subjects showed a greater performance degradation.

Three schedules of interjected naps within a 72 hour period of extended performance were used: two hour naps prior to the second and third "night" period, two hour naps following the first and second "night" period, and a single four hour nap prior to the second "night." Limited counter degradation effects were found in the final period of performance.

The largest decrements on measures were found in subjective measures, vigilance tasks, and continuous production tasks. More limited decrements or no decrements were found in the cognitive tasks and the precision measures.

Foreward

For the protection of human subjects the investigators have adhered to policies of applicable Federal Law 45CFR46.

Table of Contents

Introduction

This is the final report of a series of experiments on the effects on performance of extended time periods without sleep and with the effects of limited sleep intervals within such periods. The performance measures included subjective measures, short and long term monitoring tasks, continuous production, precision, and an extensive battery of cognitive tasks. These measures were used to test the effect of repeated periods without sleep, the performance of older persons under conditions of sleep loss, and the effects of interjected periods of limited sleep in three different schedules.

This report includes a description of the measures used and summaries of the effects of repeated sleep loss and age (Experiments I, II, III). Preliminary results of the effects on performance of short periods of sleep (4 hours) within extended periods without sleep (60 hours) are presented (Experiment IV).

Measurements

The following tests and measures were used in these experiments. The first listed are those used in Experiments I and II. These are followed by tests which were used to replace tests of the earlier experiments and were used in Experiments III and IV. The test sessions and schedules are presented in each Experiment.

Stanford Sleepiness Scale. A seven-point scale devised by Hodes et al (1973) was displayed. The subject indicated his sleepiness by referring to an integer, e.g. "(1) Almost in reverie; sleep onset soon, lost struggle to remain awake... (7) Feeling active and vital; alert; wide awake." This scale began each work session (Scale I) and was given half-way through each session (Scale II).

Mood Scale. The subjects selected an integer between 1 ('very depressed') and 10 ('elated'). This scale was also presented twice each session (Mood Scale I and II) immediately following the administration of the Sleepiness Scale.

Auditory Vigilance. The task was devised by Wilkinson (1970) and has been repeatedly used in sleep deprivation experiments. It requires monitoring 500 ms tones occurring every 2 s within an 85 db background noise. In a half-hour test, 20 test tones each 375 ms in duration, occurred at unsystematic intervals. Hits and false positives relative to the test tones were recorded.

Addition. The subject was presented with a column of five three-digit numbers to sum (Wilkinson, 1970). Each set was generated on a random basis subject with the restrictions that each of the five numbers was unique and that no more than two digits were identical within a number. Number of attempts and accuracy were measured during the 30 min self-paced task.

Word Memory. Thirty words were individually presented for 200 ms., each separated by a 1500 ms blank interval. After the last word was presented an auditory cue signalled the subject to begin recalling the materials in any order (free recall) as rapidly as possible without regard to typographical accuracy. He was later given an opportunity to edit his response protocol.

The materials for each session were drawn randomly from a pool of 390 five-letter, one-syllable, high-frequency words (e.g. words). One trial was administered per session. Number of words recalled was scored.

Word Detection. This task was a problem in signal detection. The target was a five-letter low-to-moderate frequency word and the 'noise' background consisted of five-letter non-words of the same form, i.e. consonant-vowel-consonant-vowel-consonant. Half of the 100 trials given in a session were noise trials in which 25 non-words were presented sequentially at a rate of ten items per second. On the remaining signal trials, a target word was unsystematically selected from a pool of 107 items and presented in a randomly determined location between serial positions 12 and 18. The signal trials were randomly interspersed with the noise trials, except that every block of eight trials contained an equal number of signal and noise trials. The dependent variables were the hit and false positive rates.

Visual Search. This task was an adaptation of the procedure reported by Neisser (1957). The subject was presented with an array of letters (20 rows, 7 columns) and indicated as rapidly as possible when he had detected the presence of a predefined target letter. Subjects were instructed to conduct their searches from top to bottom and left to right. The target was either 'X' or 'Q' presented within a background of either rounded letters (e.g. GOCD) or angular letters (e.g. VNKY). And 'X' embedded in angular letters or 'Q' surrounded by rounded letters defined a 'similar' condition; transposition of these targets defined a 'dissimilar' condition. Similar and dissimilar trials were given equally often, in an unsystematic order, during the 80 trials administered per session. The target appeared equally often within each row within each session. The number of targets detected for similar and dissimilar targets were recorded.

Reasoning. The task (Baddeley, 1968) required the subject to compare a simple sentence (e.g. 'A precedes B') and a pictorial relation (e.g. BA) to determine if the former was an accurate description of the latter. Subjects were encouraged to respond as quickly as possible. The eight possible combinations of 'A' as the subject versus the object of the sentence, use of 'precedes' versus 'follows', and affirmative versus negative were factorially combined. When crossed with the two possible pictorial relations (AB and BA) 16 sentence-picture combinations are formed, half of which are true. On even numbered administrations of the task the right index finger was used to depress a key to indicate a 'true' response and the left index finger to initiate a 'false' response. On the alternate administrations, this relationship was reversed. This self-paced task lasted 3 min in each administration. Number of items attempted were measured.

Remote Associates test. In this test (Mednick, 1962) the subject was presented with a word triad (e.g. 'cookie, sixteen, heart') and asked to generate the word which is associatively related to each (i.e. 'sweet'). Twenty-five triads were each displayed for 60 s, after which another set was shown even if the subject had not reported a solution. The number of correct solutions was noted.

Object Uses test. Based upon a task reported by Wilson et al (1953), the procedure required the subject to write all possible ways he could think of to describe the uses of an object. In the present instance, the subject was given a word and an illustrative common usage, and then given 2 min to generate responses. Subjects wrote their responses in script in order to eliminate typing skills as a factor. Six trials were given in each administration of the task, each with a new set of stimulus objects. The number of distinct, plausible responses given to each object was the major dependent variable.

Numerical Estimator. This task, described by Irwin et al. (1956), was modified to meet the constraints imposed by the laboratory computer. Subjects were to imagine two shuffled decks of 500 cards. On each administration of the task a set of 20 cards was selected and the top pair of cards exposed. Although it was never revealed to the subject, each sample was drawn from a deck which had been generated from a normal distibution with a mean value of zero and a standard deviation of 2.5. The subject's task was to estimate whether the mean value of the first deck was larger or smaller than the mean for the second deck, and to indicate his confidence in this judgement. The exposed cards were then covered by the next pair of cards, and the subject was allowed to adjust his reponse after incorporating the new information. This procedure continued without feedback until all pairs from the samples were exposed. The cards were returned to the master decks, shuffled, and another two sets of 20 cards withdrawn from the second block of trials. Six blocks of trials were given in each session. Accuracy and confidence were recorded for each judgement.

Line Judgement. Adapted from the classic paradigm developed by Crutchfield (1951), the task required the subject to were accurate more than 90% of the time. Subsequently, 45 difficult trials were given in which the difference in line length was small: one line was constructed of 30-45 underscores and the other lines differed by plus/minus 2 underscores. On 15 randomly determined difficult trials no feedback was given. Feedback on one of two types was given after the remining trials: on half of these the subject was informed, 'When a group of 400 men your age saw these lines, they reported that Line X was neither the longest nor the shortest,' and on the remaining trials, 'The last time you saw these three lines you reported that Line X was neither the longest nor the shortest.' While these statements were non-contingent upon a subject's response, plausibility was maintained by pointing to the correct response on one-third of the occasions. The task was made demanding intentionally to maximize the opportunity for inducing conforming responses. The dependent variables included number of accurate reports, number of incorrect responses (which were subdivided into conforming and non-conforming responses), judgemental confidence and response latency.

Unobtrusive Measures. This was a self-initiated task with two components. It was an arbitrarily defined procedural rule: Subjects were initially instructed to enter their subject code number (either the digit '1' or '2') when they began a work session, before they left for a scheduled rest break and when they returned from each break. The experimental tasks began normally whether or not the subject logged on to the laboratory computer, and the system recorded the subject's action (or failure to act). When a rest break was scheduled, the terminal displayed a message indicating this fact for 30 s. If the subject logged off appropriately within this interval, the system cleared the screen and recorded the subject's action. Otherwise, a failure to respond was noted, the screen was erased and the system was prepared for the post-break tasks.

For Experiments III and IV the Numerical Estimates task and the Unobtrusive Measures were eliminated and three tasks were added.

Digit Symbol. This test approximated the digit symbol task on the Wechsler-Bellvue Adult Intelligence Scale (1955). At the top of the computer screen nine symbols were paired above nine digits. In the middle of the screen one of the nine symbols appeared. The subject responded by pressing the appropriately matched digit. Correct or incorrect responses prompted a new symbol. The task ran for 10 minutes and was self-paced. The number attempted and percentage correct were scored.

Long Term Memory. Sets of two letters were paired with number pairs. The selection of letters permitted no duplicate letters or words, e.g. 'no' or 'to'. The selection of numbers (1-9) permitted no duplicates. On alternate administrations the sequence was letter-number or number-letter. Ten pairs were first presented for one and one-half s each. Then the stem was presented (not in the same order) and the subjects attempted to respond with the correct associate. This continued for 10 minutes or two correct trials. Approximately one hour later the stems were presented twice.

'Learning' scores were the number of pairs learned in 10 minutes. The 'Recall' measures were percentage of correct pairs recalled on the first trial compared to number of pairs originally learned.

Anagram. Three hundred and thirty common occurrence five letter words were chosen from the Thorndike-Lorge list and scrambled to form anagrams. Each five letter set could form only one correct word. The scrambled letters appeared on the screen and the subject typed in his response. A response, correct or incorrect, resulted in the appearance of a new set of letters. The task continued for ten minutes. The number attempted and percentage correct was scored.

For Experiments III and IV the Visual Search was modified to require an identification of the line in which the target appeared.

Subjects

The younger subjects of these experiments were college students between the ages of 18-22 years (Experiment I, II, III and IV). They were screened with an MMPI, a Cornell Medical Index, a sleep inventory and a personal interview concerned with general personal fitness, and a comprehensive medical examination. They were selected and accepted on a 'first come' basis if they were within normal MMPI & Cornell Index ranges, passed the medical examination, and did not maintain atypical sleep habits.

The older subjects were between 40-50 years of age (Experiment II) and 50-60 years of age (Experiment III). They were recruited by word of mouth from the faculty of the University in hopes of approximating Command Level personnel. They were also screened by the MMPI, CMI, the sleep inventory, and a comprehensive medical examination. Two individuals were rejected on the basis of the physical examination.

Experiment I

The Effects of Repeated Sleep Deprivation Periods

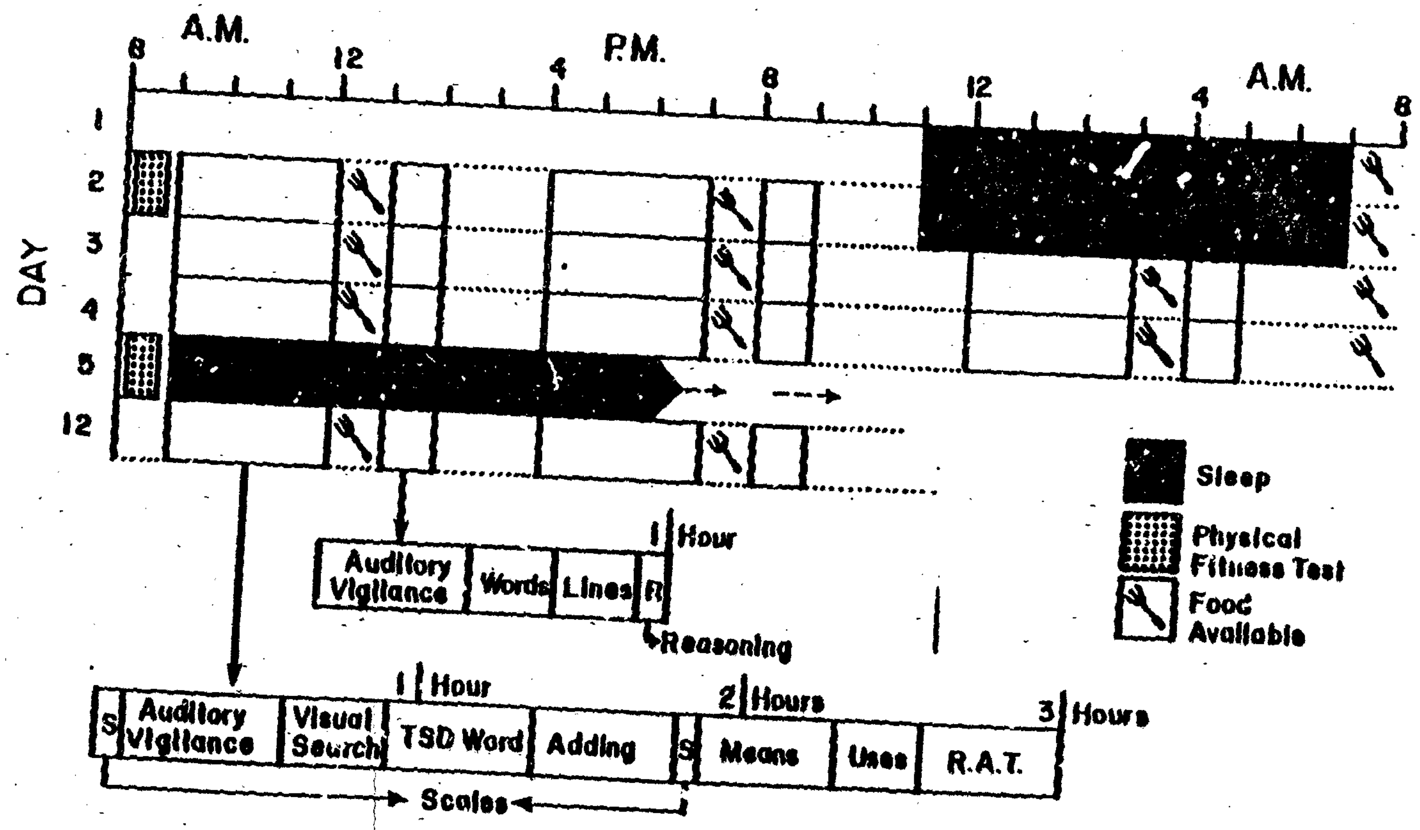
The report of this experiment has been published: Webb, W. B. and Levy, C. M. Effects of spaced and repeated total sleep deprivation. Ergonomics, 1984, 27, 45-48.

The experiment assessed the effects of the repetition of spaced periods of sleep deprivation. Six young subjects (18-22 years of age) participated in a schedule of sessions presented in Figure 1. At three week intervals thereafter the subjects reported to the lab on five occasions. The repeated sessions included a night of laboratory sleep (11 PM to 7 AM) and the sequence outlined in Figure 1 for Days 3, 4, and 5. There was no return testing on Day '12'. In short the subjects remained in the laboratory for testing without sleep for two days and two nights and slept at the beginning of the third day.

The baseline of non deprived measures was the first period of testing of the repetition session for the third and fourth deprivation periods (the recovery period after 12 days was used for Session I). Thus the first period of deprivation Session III served as the baseline for Session II, etc. These were selected as measures which included all prior learning or additional carryover effects associated with deprivation testing. The deprivation measures were those of the testing periods of maximum deprivation of the second night without sleep. A Deprivation X Repetition X Subjects ANOVA was utilized for analyses.

Those tests which typically are sensitive to sleep deprivation --Subjective Scales, Auditory Vigilance and Addition -- showed significant deprivation effects. Line Judgement was not analyzed and Visual Search was found to be technically flawed. Word Detection and Numerical Estimation did not yield significant results. Deprivation effects were significant for the Word Usage, Reasoning and Remote Associates tasks.

Figure 1. Schedules of sessions and tests within sessions - Experiment I and II.



The Subject X Deprivation was significant for a number of tests which, on further analysis, was primarily attributable to the differential responses of individual subjects to deprivation. This finding suggests that some tests may be selected to determine inidividual sensitivity to sleep deprivation effects.

In general the effects of repetition were either negligible, as illustrated by the Sleepiness Scale measures (Figure 2), or there was a parallel decline in measures as illustrated by the Vigilance Score measures (Figure 3). The conclusions about these effects are summarized in the discussion:

"Two possible consequences of repeated periods of sleep deprivation on repeated measurement performance were hypothesized. As suggested by Wilkinson (1961), there may be an increased response deficit displayed due to lowered motivation ('boredom', 'decreased challenge', etc.)--a variable which exacerbates sleep deprivation effects. Alternatively, there may be a reduction in the effects of sleep deprivation as tasks become overlearned and "automatic" or "stress" effects are reduced and "coping" mechanisms developed. Either alternative would result in differential and opposite effects when compared with baseline performance. If Wilkinson is correct, the differences should increase with repeated deprivation. If the alternative is correct, deprivation should diminish the differences."

The data clearly support the position outlined by Wilkinson. Most of the tests showed a decline in performance across sessions in both the non-deprived and deprived conditions. This can be most parsimoniously interpreted in terms of effects of reduced motivation. There was evidence that this reduced level of motivation is differentially enhanced by the deprivation effects. A direct comparison of non-deprived vs. the deprived conditions of Session I and Session IV showed sharp increases in the sensitivity to deprivation effects in the second Auditory Vigilance Test, Word Memory (response time) and Object Usage. Two significant Deprivation X Sessions interactions were noted. The Reasoning test displayed an increased performance during baseline sessions but no change during deprivation. This result can be interpreted with the motivational context. The Remote Associates Test showed a paradoxical increased efficiency during deprivation."

A number of cognitive and information processing tests were used in the testing battery. When compared with the less demanding and more time extended tasks such as Vigilance and Addition, they were, in general, less effective in detecting deprivation and continuous performance effects. These findings are in accord with the now well-established differential task related sensitivity to sleep loss and continuous performance (Nation, 1968). Short term and more challenging tasks which generally characterize the cognitive battery were less sensitive to the motivational assessments. However, Object Usage, Word Memory, and the Reasoning test did not yield positive results using limited scoring criteria."

"In operational terms, the results indicate that repeated experiences with sleep loss and continuous performance are not likely to result in the development of compensatory or coping tendencies which will affect performance decrements. Rather, such experiences may exacerbate these effects. Probably as a result of decrements in motivation. Moreover ...

Figure 2. Sleepiness Scale values across repetitions of deprivation. Solid dlines are baseline scores; dotted lines are deprivation scores.

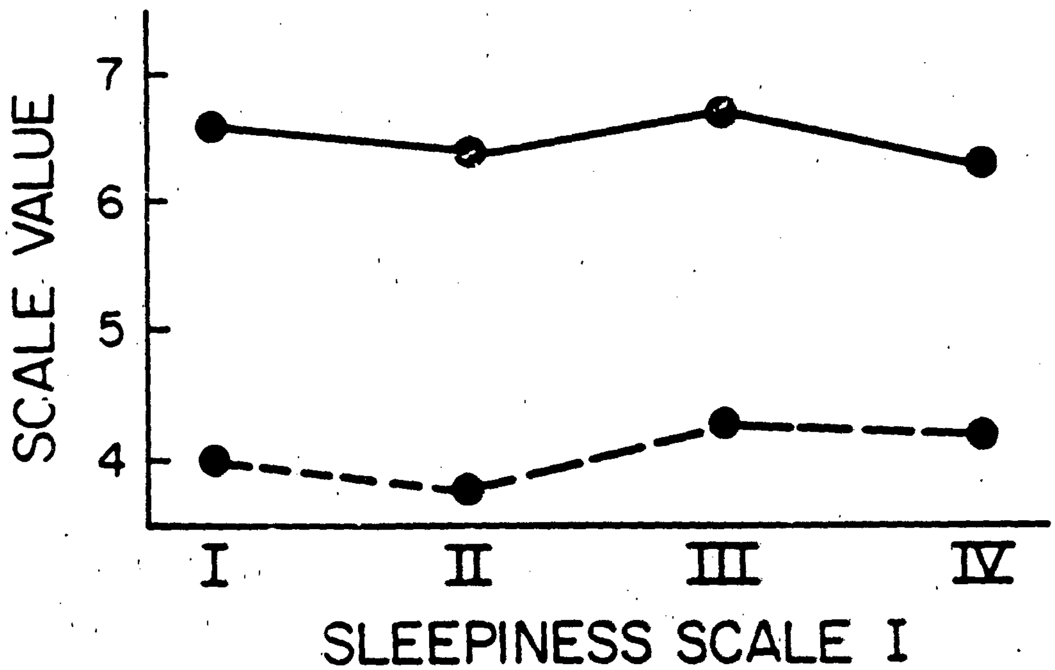
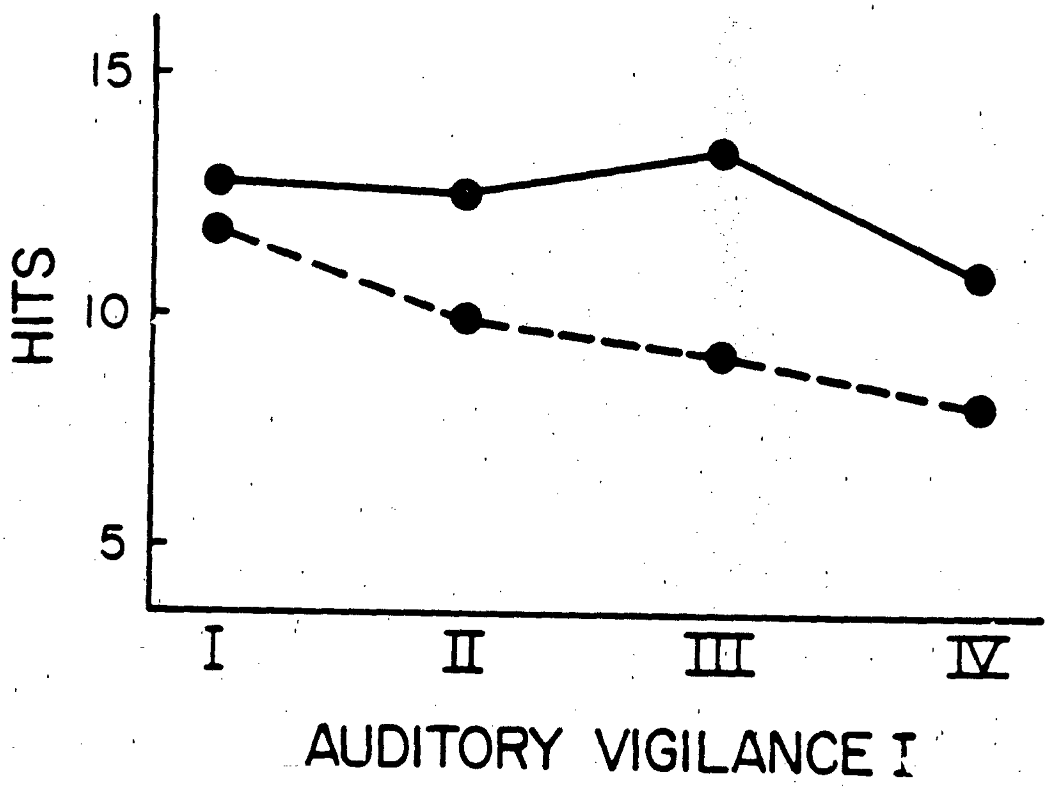


Figure 3. Auditory Vigilance Scale values across repeptition of deprivation. Solid lines are baseline scores; dotted lines are deprivation scores.



these effects to be task-related in a manner previously noted in single deprivation studies (Webb & Levy, pp. 57-58)."

Experiment II

Sleep Deprivation, Age and Performance

The results of this experiment have been reported (Age, sleep deprivation and performance. Webb, W. B. & Levy, C. M. Psychophysiology. 19. 272-276, 1982.

This experiment was concerned with the effect of age on performance associated with sleep deprivation. The performance of 6 younger subjects (18-22 years) were compared with those of ten older subjects (40-49 years). The younger subjects were those of Experiment I in their first deprivation session.

The schedules and tests were those presented in Figure 1 (Experiment I). The Day 12 data (performance after 7 days of home sleep) were used for baseline data and the tests given after the most extended deprivation during the second night were the deprivation data.

Separate Subjects X Deprivation analyses were conducted on the Younger and Older groups and a Type I ANOVA was used to assess the Age X Deprivation effects. The primary results are shown in Table I.

As noted in the reference paper: "Those test showing robust deprivation effects were generally those previously demonstrated to be sensitive to sleep deprivation: The Sleepiness and Mood Scales, Auditory Vigilance, and Addition tasks. With the exception of the subjective scales, significant effects were either dependent upon age or were more reliable in the older group. Of the cognitively demanding tests, only Object Uses (Number), Visual Search, and Reasoning (Number Attempted) yielded a significant deprivation effects, and these were confined to the older subjects. While significance figures cannot be strictly compared, it s clear from the first two columns of Table II that greater sensitivity to derivation occurred in the older group. Indeed, this relative differential sensitivity accounts for all of the Interactions noted in the last column of Table I with the exception of the Mood Scales (Webb & Levy, 1982)."

The conclusions stated in that paper were as follows:

"The data empirically indicates that deprivation effects are greater in older subjects both with tests which emphasize speed of performance (e.g. Visual Search, Reasoning and Object Usage) and those which do not (Auditory Vigilance). However, the simple interpretation of an "age" effect per se is not simply due to differences in initial performance levels in the two groups with the older subjects generally giving higher performance scores. This could reflect higher initial motivation in the older subjects which could not be sustained across the deprivation period. However, this explanation is clouded by the higher subjective measures (Sleepiness and Mood Scales) in the younger subjects. Alternatively, higher performance levels may be more susceptible to sleep deprivation and continuous performance. Unfortunately, we can find no data in the literature on an age controlled group to resolve this possibility. Our subjective observa-

Table I

Summary of Tests Showing Statistical Effects of Experiment II.

p Values

Tests+	Younger Dep	Older Dep	Age x Dep		
			Age	Dep	A x D
SS I	.00*	.00	-	.00	-
SS II	.01	.00	-	.00	-
MS I	.01	.00	-	.00	.06
MS II	.01	.00	-	.00	.06
AVI (Hits)	.05	.01	-	.00	-
AVII (Hits)	.20	.03	-	.01	.18
AVI (False +)	-	.11	-	-	.13
ADD (Attempts)	.17	.03	-	.01	-
ADD (Time)	.18	.03	-	.01	-
OBJ (N)	-	.00	.01	.00	.03
VS (Similar)	-	.03	-	.08	.02
VS (Dissimilar)	-	.04	-	-	.10
REA (N)	-	.08	.00	-	.03
REA (%)	-	-	.00	-	-
RA	-	-	.00	-	-
WD Mem	-	-	.00	-	-

+ SS = Sleepiness Scale, MS = Mood Scale, AV = Auditory Vigilance, ADD = Adding, OBJ - Object Uses, VS = Visual Search, REA = Reasoning, RA = Remote Associates, WD = Word Detection

* p .001.

tions of the subjects inclines us toward a belief in an aging effect (Webb & Levy, 1982)."

Additional Findings

Two further results from the data of Experiment II have been published: Webb, W. B., Kaufmann, D. A. and Levy, C. M. Sleep deprivation and physical fitness in young and older subjects. Journal of Sports Medicine. 21, 198-202, 1981; Webb W. B. Sleep stage responses of older and yonger subjects after sleep deprivation. EEG & Clin. Neurophysiol. 52, 368-371, 1981.

It was found that cardiovascular, respiratory and muscular systems measures showed no debilitating effects as a result of two nights of sleep deprivation. This study utilized the ten (40-49 yr. old) subjects as well as the six younger subjects which extended the range of physical fitness measures.

The subjects of Experiment II (18-22 yr. old subjects) were encephalographically recorded during their first period of recovery sleep after two nights of sleep deprivation. The results were summarized as follows:

"EEG sleep stage measures were obtained on younger subjects (18-22 yr.) and older subjects (40-49 yr.) at 9 AM after 2 nights of sleep loss. The first 200 min. were compared. Both groups displayed sharply reduced latencies and increased Stage 4 sleep. The proportionate distribution of stage amounts and numbers were not different. However, the younger group entered slow wave sleep more quickly (Webb, 1981)." These data are presented in Figure 4.

Experiment III

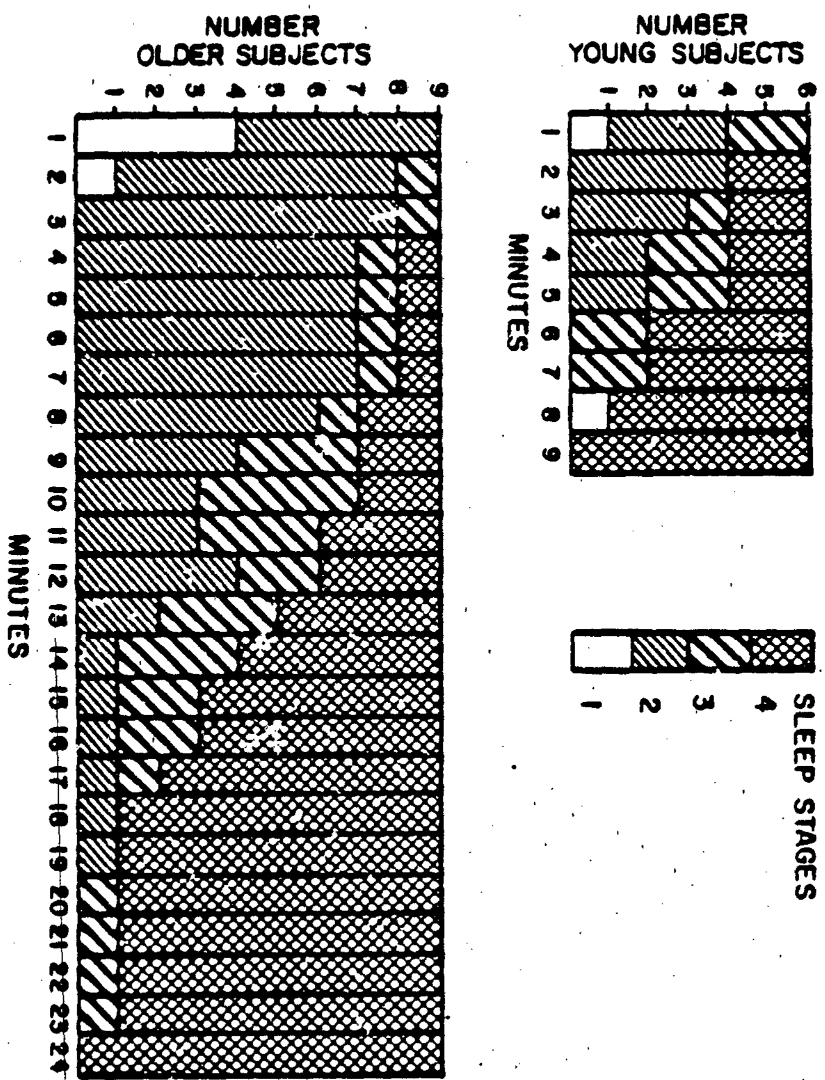
The results of the experiment have been reported (Webb, W. B. A further analysis of age and sleep deprivation effects. Psychophysiology. 1984. (In press).

This experiment was an extension of Experiment II. The experiment used twelve 50-60 year old subjects and compared their performance to a group of six younger subjects (18-22 years). The test battery was modified by the elimination of the Numerical Estimates Test and replacing it with the Anagrams test, Digit Symbol Substitution and Learning-Long Term Memory task.

The measures were grouped into four categories: Subjective, Persistence/Attention, Precision, and Cognitive. The Discussion of the paper summarizes the findings:

"In brief summary the younger subjects showed sharper declines in Subjective Scales. For the Persistence/Attention scores on four tests the older subjects showed significant declines while the younger subjects did not. One Precision test showed an interaction which resulted from decline from a higher baseline level in the younger subjects to equal performance during deprivation. Two of the cognitive demand tasks showed sharper declines by older subjects and two showed the pattern of high initial performance by younger subjects and sharper declines to equal performance under deprivation. In brief, in these age ranges, where a differential effect was found, the older subjects showed less decline in the subjecive ratings but greater decline in tests of persistence/attention, pre-

Figure 4. Recovery sleep after two nights of sleep loss for younger and older subjects. Initial minutes of sleep by stages are shown.



cision, and cognitive processing. Where there were exceptions, these reflected higher levels of baseline performance by the younger subjects to equal performance under deprivation."

The sharper decline of the younger subjects on the subjective tests is illustrated by Figure 5 (Mood Scale) while the sharper declines of the older subjects on attention tasks is illustrated by Figure 6 (Auditory Vigilance).

The report also notes that: "Briefly then the data of our study relative to kinds of measures which are more or less sensitive to the effect of sleep loss reflect the history of efforts at measuring sleep loss (Johnson & Naitoh, 1974): Subjective and persistence/attention measures are highly sensitive to sleep loss effects whereas precision and cognitive processing tasks are less sensitive.

Finally, it was noted that there was a general tendency for there to be an increase in variability of scores from the non-deprived to the deprived condition, and greater variability among the older than the younger subjects.

Experiment IV

In continuous operations it is possible that limited opportunities for sleep may be available. It is crucial to determine their potential as counter degradation measures. It appears from the work of Haslim (1982) that limited sleep does offset sleep loss effects in a task differential manner in field operations. The experiments of Naiton (1982) indicate the placement of such sleep periods may be important.

The present experiments assess the effects of the placement of 4 hours of sleep within a 72 hour period without sleep. Three sleep schedules of four hours of sleep were used: two sleep periods of two hours placed at 10 PM to 12 Midnight ("preparatory" sleep), two sleep periods placed at 8 AM to 10 AM ("recovery" sleep), and four hour evening blocks from 8 PM to 12 Midnight. These schedules of sleep, tests, and free time for the groups are diagrammed in Figure 7.

The tests used are described in an earlier section. The arrangements of the tests in batteries and their scheduled administration across the three days of testing is shown in Table II.

Results

The deprivation measures of these analyses are the test results taken from the test sessions of maximum deprivation. They were drawn from Batteries A, B, and C which were administered between 12 Midnight (0000) - 6 AM (0600) of the third night of sleep deprivation. The baseline measures were the test results from the recovery period tests administered between 10 AM (1000) and 4 PM (1600) after seven days of home sleep. These non sleep deprived measures thus included all of the practice/adaptation effects present for the deprivation measures. For the subjective scales the summed measures obtained in all three batteries were used. For the Addition test the summed scores of Batteries B and C were used.

An ANOVA was calculated using the components of Nap Type

Figure 5. Mood Scale scores of younger and older subjects. Solid line is younger subjects and dotted line is older subjects. ND are baseline scores and deprivation scores.

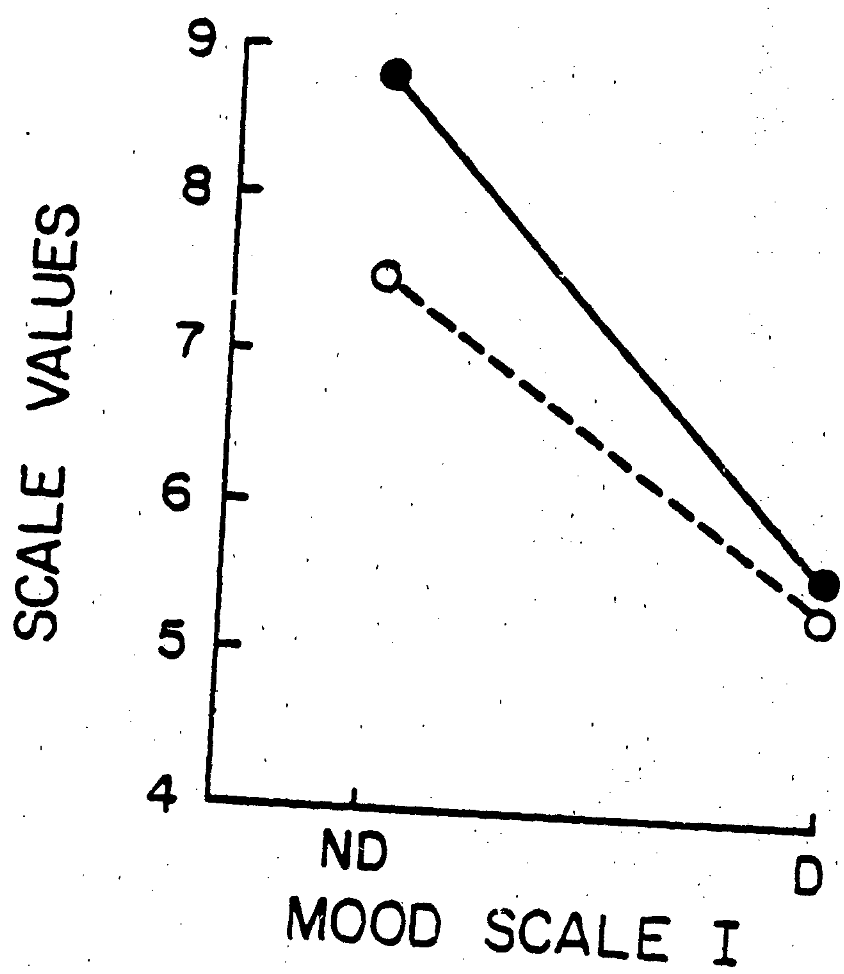


Figure 6. Auditory Vigilance scores. See Figure 5.

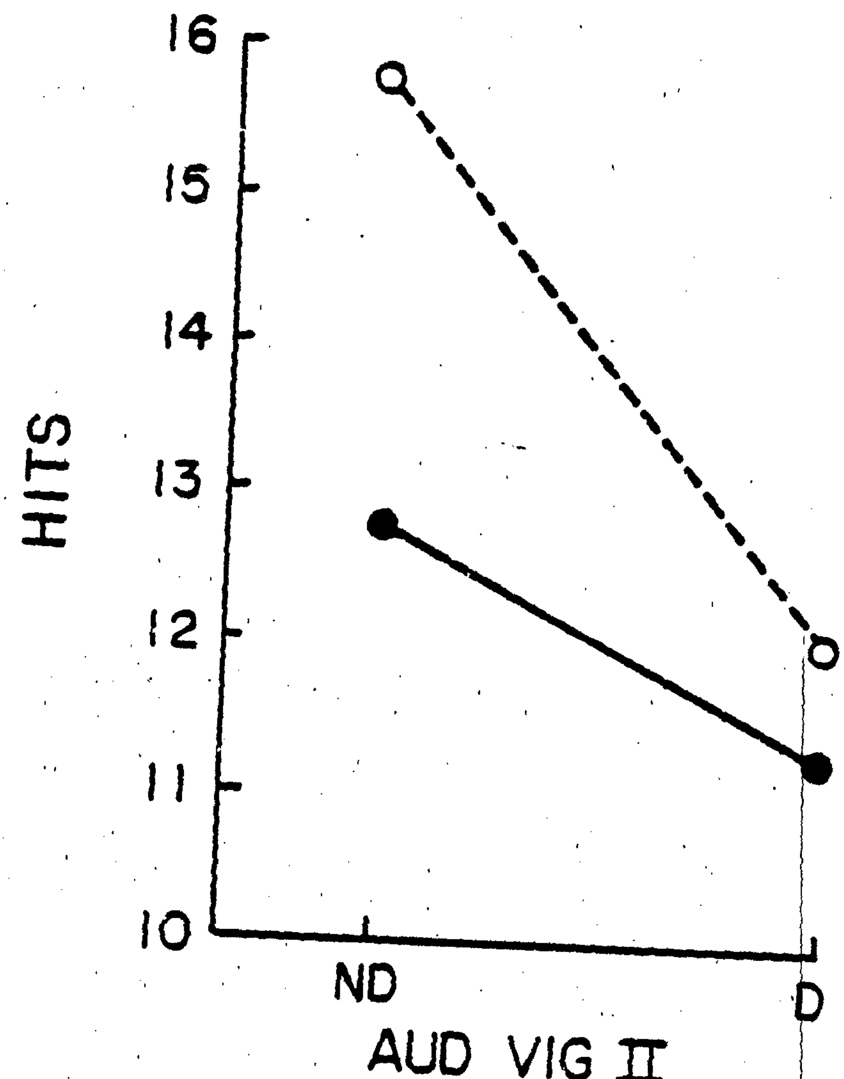
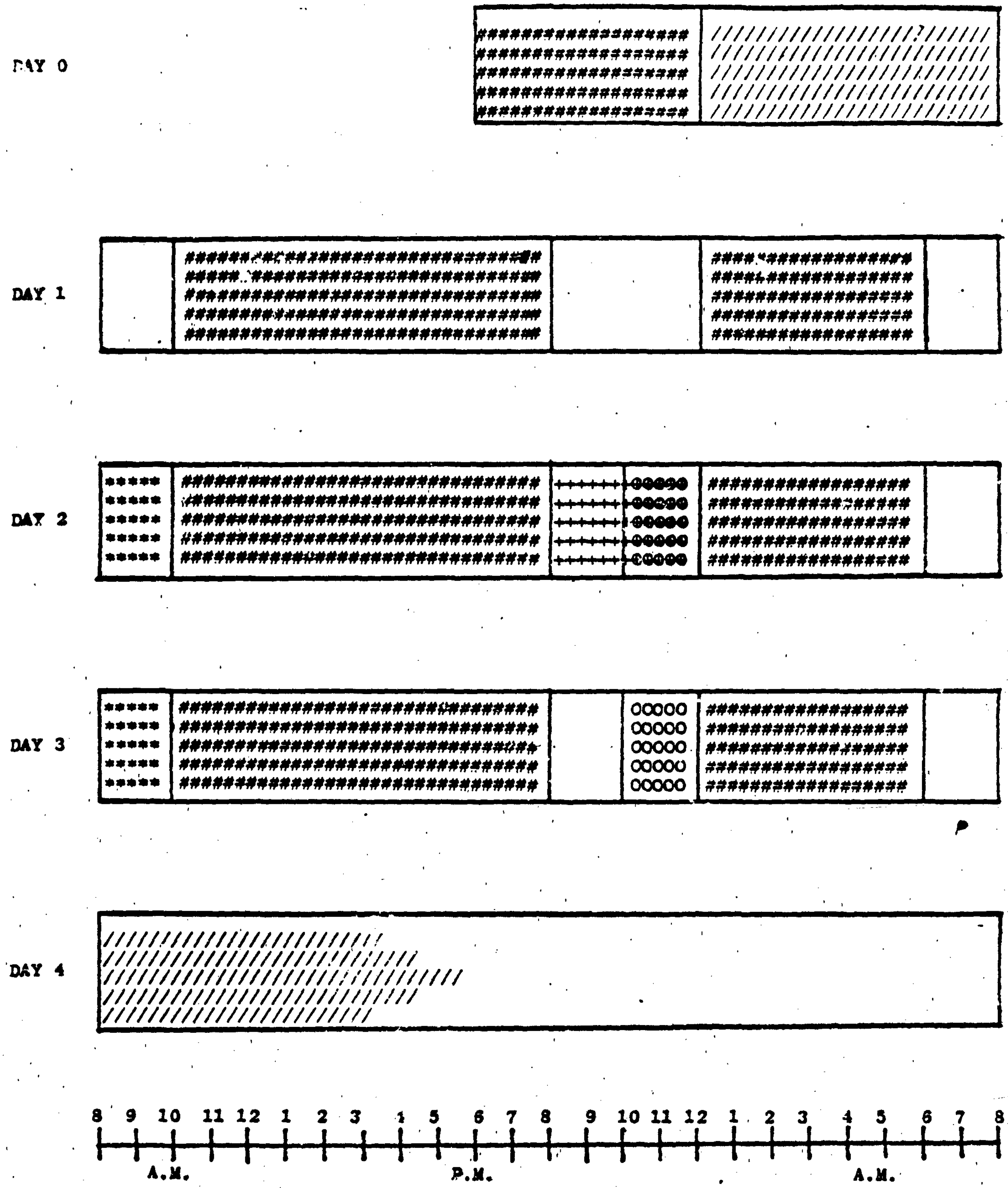


Figure 7. Schedule sessions and testing for Experiment IV.



Testing
///// All groups sleep
***** Group A sleep - 2 hours twice
OOOOO Group B sleep - 2 hours twice
+++++ Group C sleep - 4 hours once

TABLE II

Test Schedules for Experiment IV

Test Batteries

Battery A: Sleepiness and Mood Scales (3 m), Auditory Vigilance (30 m), Word Memory (10 m), Visual Search (20 m), Line Judgement (12 m), Reaction Time (10 m,, Anagrams (10 m), Reasoning (30 m), Scales (3 m).

Battery B: Scales (3 m), Long Term Memory-Learning (10 m), Addition (30 m), Uses (20 m), Digit Symbol (15 m), Long term Memory-Testing (5 m), Scales (3 m)

Battery C: Scales (3 m), Addition (30 m), Word Detection (30 m), Anagrams (10 m), Scales (3 m).

0800 1000 1200 1400 1600 1800 2000 2200 2400 0200 0400 0600 0800

	A	B	C	B	A			A	B	C	

(no nap, morning naps, evening naps, and 4 hr. naps), Deprivation (Deprived and Non Deprived), and Subjects. This analysis yielded sources of Nap Type (3 d.f.), Deprivation (1 d.f.), Nap Type x Subjects (20 d.f.), Deprivation x Nap Type (3 d.f.), and Subjects x Nap Type x Deprivation (20 d.f.)

Sensitivity to Deprivation: Using the S x NT x D as an error term, the deprivation effect was evaluated for each test. Table III lists the measures whose F values exceed the 10% level of confidence and those that did not. The table has been divided into four groupings of tests based on a logical assessment of the measures (Webb, 1983). For those tests having significant deprivation effects, the percentage decline of the measures (100-B/D) is given.

A number of strategies may be used to evaluate the differential effects of our experimental conditions which involve a baseline measure and a measure of an intervening effect (Cronbach, 1970 and Harris, 1963). The simplest model recommended by Cronbach may be considered equal. In this model one tests for differences between the outcome or dependent measures to determine if the intervening treatments had a differential effect.

Applying this model to those tests which displayed significant deprivation effects, simple treatment ANOVAs were applied to scores of the baseline scores of the four groups to test for the assumption of homogeneity of initial performance levels. The null hypothesis could be rejected at the 10% level of confidence for two of the tests: Vigilance (% hits) and Line Judgement (Correct feedback).

Next the treatment ANOVA was applied to the Deprivation scores. The null hypothesis could be rejected at the 10% level of confidence for measures: SS2 (.02), Word Search Hits (.06), Word Search False Alarms (.09), and Line Judgement (Correct).

Table IV presents the deprivation measures of Sleepiness Scale II, Word Search hits and false alarms, and the Line Judgement and Vigilance measures for both the Baseline and Deprivation measures. These differences were further explored by t tests and these results noted in Table IV.

Test Sensitivity:

In accord with our earlier experiments, the Subjective measures and the Persistence/Attention measures continued to reveal robust derpivation effects. Again, however, our extended measures of Precision and Cognition tests met with limited success. The previously effective Object Usage, Visual Search (Similar) and Reasoning tests (Experiments II and III) were not sensitive. It is to be noted that the obtained effects were confined to the older subjects in the earlier experiment and the present data on younger subjects reaffirms the resistance of cognitively demanding tasks to deprivation effects. Of the three cognitive tasks which were added to the battery (Long Term Memory, Anagrams, and Digit Symbol) only Digit Symbol yielded promising results.

Two significant differences in baseline performance in the Line Judgement (c) task and the Vigilance (%) task makes the interpretation of these data equivocal in this model but the pattern of the scores indicate that the differences in deprivation scores simply reflect the baseline differences. The

Table III

Tests with Significant and Non Significant Deprivation Effects (p .10)

	Significant		Non Significant
Subjective	Sleepiness Scale I	- 34%	
	Sleepiness Scale II	- 44%	
	Mood Scale I	- 26%	
	Mood Scale II	- 30%	
Persistence/ Attention	Addition (N)	- 20%	Visual Search (S)
	Vigilance	- 20%	
	Word Search	- 7%	
	Visual Search (D)	- 7%	
Precision	Addition %	- 3%	Reasoning %, Digit Symbol % Anagrams %, Vigilance (False)
	Word Seardh (False Alarms)	- 34%	
Cognitive	Digit Symbol	- 22%	Anagrams(N), Reasoning(N), Uses, Line Judge (Inc), Long Term Memory (Learn), Long Term Memory (Recall.
	Word Memory	- 26%	
	Line Judge (C)	- 17%	

Table IV

Means and Significance Levels of t Tests of Significant ANOVAs

	Sleepiness Scale				Word Search (N)				Word Search (FA)			
	Morn	Even	Four	Mean	Morn	Even	Four	Mean	Morn	Even	Four	Mean
	-	.06	-	9.5	.02	-	-	24	.00	.00	.00	14.5
		.09	.12	10.2		.11	.02	41		-	-	5.2
			.01	13.2			-	34			-	5.5
				8.0				31				5.0

Line Judgement (C)

	Base/Dep	Base/Dep	Base/Dep	Base/Dep	Base/Dep
No Nap	00/00	-/-	-/-	4.3	3.8
Morn		-/.04	.03/.06	13.5	12.6
Even			-/-	9.7	7.0
Four				7.7	5.8

Vigilance Hits (%)

No Nap	10/-	.00/.03	-/-	49	40
Morn		.04/-	-/-	68	52
Even			-/-	87	70
Four				68	57

Figure 8. Word Search False Alarms. The dotted line presents the deprivation period data.

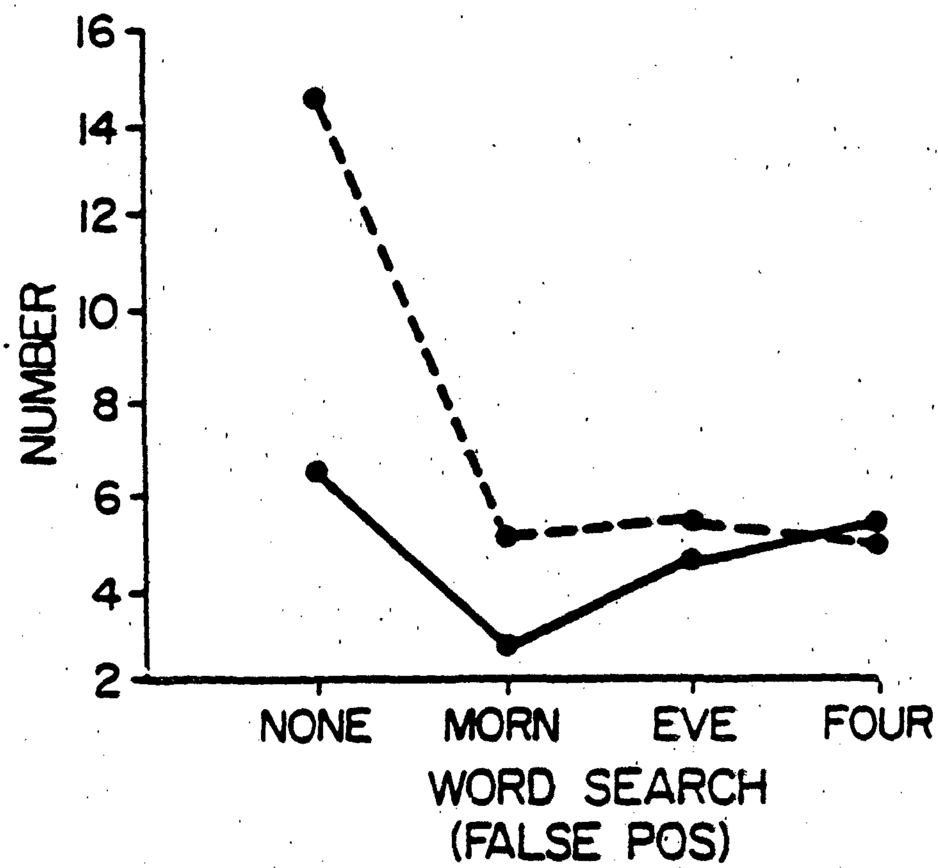
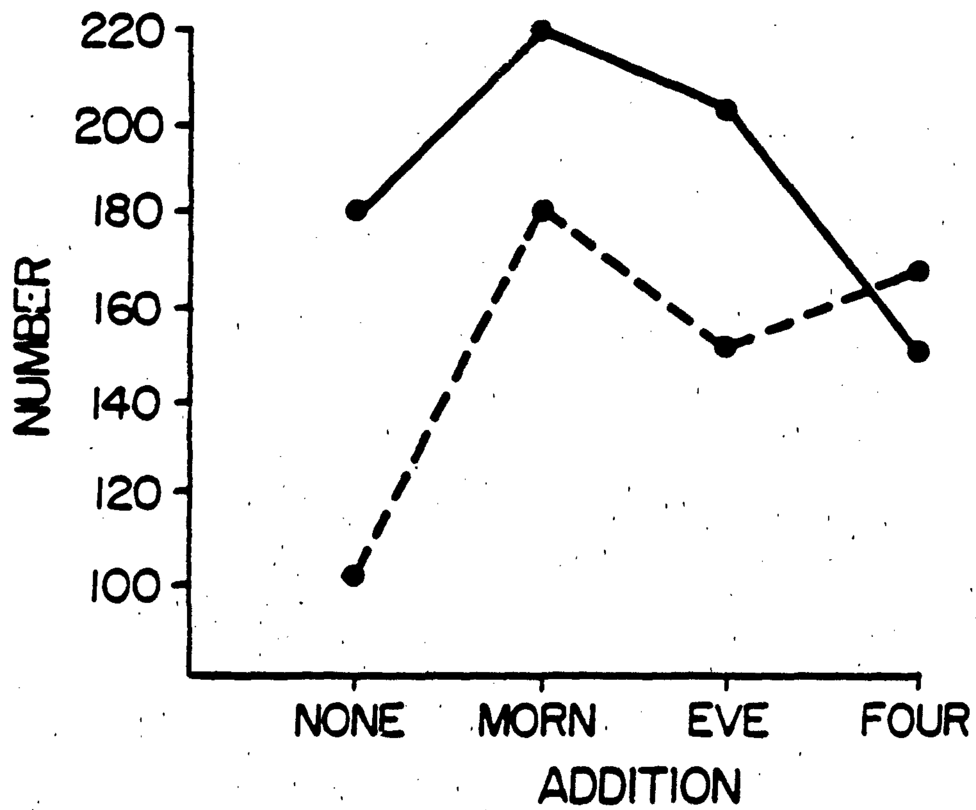


Figure 9. Addition Attempts. The dotted line presents the deprivation periods data.



remaining tasks (Sleepiness Scales, Word Search Hits and False Alarms) yield mixed results. The Sleepiness Scale results can be attributed to the superior performance of the Evening Nap group, the Word Search Hits to the superior performance of the Morning Nap group and the Word Search False Alarms to the inferior performance of the No Nap group.

An alternative strategy for determining the differential effects is by the use of the Nap Type x Deprivation interaction variance. A significant F ratio indicates a differential level of response of the groups to the treatment effect. As noted in the initial ANOVA, a Nap Type x Deprivation variance was derived and the Nap Type x Deprivation x Subjects may be used to test significance. Two tests were significant at greater than the 10% level of confidence: Word Search and Addition Attempts. To assess the nature of these interactions, these scores are plotted in Figures 8 and 9.

The Word Search False Alarms were essentially a function of the much poorer performance of the No Nap group. This is clearly supported by the data of Figure 8. The addition task effects can be attributed essentially to the lack of deprivation effects by the 4 hour group (Figure 9).

Discussion

Naitoh, Englund & Ryman (1982, 1983) have reviewed the limited literature on "naps" and performance with particular reference to the use of limited sleep periods in continuous operations as ameliorative resources. Their review points to six variables which may determine performance: 1) length of the deprivation period, 2) length of the nap period, 3) placement of the nap period, 4) time of performance in relation to the nap period (sleep lag), 5) time of task performance, 6) the performance task.

Within this framework the present analysis are referent to 1) performance during the third night of sleep loss, 2) schedules of two two-hour sleep period and a four hour sleep period, 3) evening and morning placements of sleep, 4) performance at least 16 hours after the sleep interval (no sleep lab), 5) during a circadian low period (0000-0600), and 6) on a wide range of tasks.

Only four measures of 13 deprivation sensitive measures yielded between treatment differences. For one of these the difference could be interpreted as reflecting baseline level differences. An alternative analysis indicated a conditions effect in one additional test. There was no consistency among these results; the four tests favored the evening nap (one test), the morning nap (one test), the four hour nap (one test), and the three nap conditions (one test).

In general our findings which were unaffected by sleep lag indicated limited counter degradation effects resulting from two two-hour sleep periods or 4 hours of sleep in their time placement. This was on a wide variety of deprivation sensitive measures (subjective, persistence/attention, precision, or cognitive) taken after substantial periods of wakefulness (60 plus hours) and at a low circadian period (0000-0600).

The limited effects of the two hour naps are in accord with the conclusions of Naiton et al's review: "In summary, it seems that two hours of recovery sleep, taken at the periods of 2000-0200 (Morgan et al, 1973), 2300-1000 (Akerstadt & Gillberg, 1979), 2300-0130 (Rosa et al, In press) or 0400-0600 (Naitoh, 1982), has too little restorative power over sleepiness and fatigue resulting from CW (continuous work)."

The results obtained from the 4 hour nap condition, however, do not agree with the conclusions of the review: "It could also be concluded...that a 4-hour long recovery period would have considerable restorative power." Two studies (Akerstadt & Rosa), who used an awakening from sleep design, and Morgan et al who used an immediate testing design found a significant recovery effect following four hours of sleep. Haslim (1982) found recovery effects after three days of sleep loss resulting from four hours of sleep per night in a field study, and Naitoh et al (1982) reported significant recovery effects on one test (but not on others) from three hour naps.

A primary difference is our design compared with the others was the interjection of the four hour nap 24 hours prior to the period of testing, and the test period was conducted during a circadian low period (0000-0600) which extended the period of deprivation. As a consequence, while the four hour nap may have been "restorative," it was not sufficient to offset the continued deprivation and circadian effects. It should further be noted that the most comparable studies (Haslim & Naitoh) did, in fact, report limited recovery effects from a single period of three or four hours of sleep (as used here) and that Haslim found a resistence to recovery during a low circadian period.

In conclusion, our laboratory results indicate little counter degradation effectiveness of four hours of sleep within a 60 hour period of performance demands without sleep. It should be emphasized, however, that these results were obtained in a non stress environment and does not refer to the relief which may be associated with such intervals in stress or field conditions.

On the positive side, two points should be noted. When buffered from sleep lag effect, no decremental effects were associated with the interjected sleep period. Secondly, within the third night of extended performance, the primary depradation of measures was confined to subjective measures and measures involving relatively long term attention and persistence of production. Cognitive and short term attentual tasks showed limited deterioration.

A summary report of these experiments with a more detailed anaslysis of Experiment IV is in press in a special issue of <u>Behavioral Research Methods, Instruments, and Computers</u> (Webb, 1985, In press). Additional analyses of these data, currently underway, indicate significant counter degradation or recovery effects associated with the nap periods in the sessions following the naps.

Publications and References

Webb, Wilse B. Sleep stage responses of older and young subjects afer sleep derprivation. Electroencephalography and Clinical Neurophysiology. 1981, 52, 368-371.

Webb, Wilse B. A further analysis of age and sleep deprivation. effects. Psychophysiology. 1984, In Press.

Webb, W. B., & Levy, C. M. Age, sleep deprivation, and performance. Psychophysiology. 1982, 27, 272-276.

Webb, W. B., & Levy, C. M. Effects of spaced and repeated total sleep deprivation. Ergonomics. 1984. 27, 45-58.

Webb, W. B., Levy, C. M., & Kaufmann, D. Sleep deprivation and physical fitness in young and older subjects. Journal of Sports Medicine. 1981. 21, 198-202.

Reference

Akerstadt, T., & Gillberg, C. Effects of sleep deprivation on memory and sleep latencies in connection with repeated awakenings from sleep. Psychophysiology. 1979, 16, 49-52.

Baddeley, A. D. A 3-min reasoning test based on grammatical transformation. Psychonomic Science. 1968, 10, 999-1005.

Cronbach, L. J., & Furby, L. How should we measure "changes" - or should we? Psychological Bulletin. 1970, 74, 68-80.

Crutchfield, R. Assessment of persons through a quasi group-interaction technique. Journal of Abnormal and Social Psychology. 1951, 46, 577-588.

Harris C. W. (Ed.). Problems in Measuring Change. Madison, Wisconsin. University of Wisconsin Press, 1963.

Haslim, D. P. Sleep loss, recovery sleep, and military performance. Ergomonics. 1982, 25, 163-178.

Hodes, E., Zarcone, V., Smythe, H. R., & Dement, W. C. Quantification of sleepiness: a new approach. Psychophysiology. 1973, 10, 431-436.

Irwin, F. W., Smith, W. A. S., & Mayfield, J. R. Tests of two theories of decision in an expanded judgement situation. Journal of Experimental Psychology. 1956, 51, 261-268.

Johnson, L. C., & Naitoh, P. The operational consequences of sleep deprivation and sleep deficit. AGARD Report, AG-193, 1974.

Mednick, S. Associative norms for the creative process. Psychological Review. 1962, 69, 220-232.

Morgan, B. B., Coates, D. C., Brown, B. R., & Alluisi, E. A. Effects of continuous work and sleep loss on the recovery of sustained performance. U. S. Army Tech. Memo 14-73, Human Engineering Laboratory, Aberdeen Proving Ground. Maryland, 1973.

Naiton, P. Sleep loss and its effects on performance. Naval Medical Research Unit Report 68-3, Washington, Naval Bureau of Medicine and Surgery, 1968.

Naitoh, P., Englund, C., & Ryman, D. Restorative power of naps in designing continuous work schedules. Report 82-25, Naval Research and Development Command, Bethesda, Maryland, 1982.

Naitoh, P., Englund, C., & Ryman, D. Extending human effectiveness during sustained operations through sleep management. Report 83-13, Naval Research and Development Command, Bethesda, Maryland, 1983.

Neisser, U. Cognitive Psychology. New York: Appleton-Century-Croft, 1957.

Rosa, R. R., Bonnet, M. H., & Warm, J. W. Recovery of performance during sleep following sleep deprivation. Psychophysiology. In press.

Webb, Wilse B. Sleep stage responses of older and younger subjects after sleep deprivation. Electroencephalography and Clinical Neurophysiology. 1981, 52, 367-371.

Webb. Wilse B. A further analysis of age and sleep deprivation effects. Psychophysiology. In press.

Webb. W. B., & Levy, C. M. Age, sleep deprivation, and performance. Psychophysiology. 1982, 19, 272-276.

Webb, W. B., & Levy, C. M. Effects of spaced and repeated total sleep deprivation. Ergonomics. 1984, 27, 45-58.

Webb, W. B., Levy, C. M., & Kaufmann, D. A. Sleep deprivation and physical fitness in young and older subjects. Journal of Sports Medicine. 1981, 21, 198-202.

Webb, W. B. Behavioral Research Methods, Instruments, and Computers. 1985. (In press).

Wechsler, D. Manual for the Wechsler Adult Intelligence Scale. New York: Psychological Corporation, 1955.

Wilkinson, R. T. Interaction of lack of sleep with knowledge of results, repeated testing and individual differences. Journal of Experimental Psychology. 1961, 62, 263-271.

Wilkinson, R. T. Methods for research on sleep deprivation and sleep function. In E. Hartmann (Ed.). Sleep and Dreaming. Boston: Little Brown, 1970.

Wilson, R. C., Guilford, J. P., & Christenson, P. R. The measurement of individual differences in originality. Psychological Bulletin. 1953, 50, 362-370.

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